IMPROVED TECHNOLOGIES TO ALLEVIATE WORKER HEAT STRESS

Steven J. Bossart
U.S. Department of Energy
DD&D Focus Area
P.O. Box 880
Morgantown, WV 26507-0880

Harold D. Shoemaker, Ph.D.
U.S. Department of Energy
DD&D Focus Area
P.O. Box 880
Morgantown, WV 26507-0880

Kenneth M. Kasper, CHP
Waste Policy Institute
1224 Pineview Drive
Morgantown, WV 26505

Introduction

The Deactivation, Decontamination, and Decommissioning (DD&D) Focus Area within the Department of Energy's (DOE) Office of Science and Technology strives to develop and demonstrate innovative technologies to reduce cost, accelerate schedule, and reduce health and safety risks associated with deactivating and decommissioning (D&D) DOE's surplus contaminated facilities. Worker health and safety is an important part of the DD&D Focus Area's efforts and improvements are being sought in personal protective equipment (PPE). Current PPE protects workers from hazardous and radioactive materials encountered in D&D projects, but the clothing is noncooling and often nonbreathable which can result in worker heat stress.

Why Are Improvements Needed to Control Heat Stress?

Cumbersome protective gear, hot summer temperatures, indoor work in nonventilated areas, and physically demanding work hinder a worker's ability to remain cool. D&D activities usually involve at least one and sometimes involve all of these factors. A worker's inability to shed excess heat can result in heat stroke. Heat stroke is rare, but very serious. Less serious consequences of heat stress are more common but also can have adverse impacts. As a worker's body temperature rises and departs from the comfort zone, productivity and quality of work are likely to diminish, and the risk of accident increases. Excessive body heat impairs judgment, reduces muscle motor response, and creates an undesirable condition for performing tasks. Alleviating heat stress will promote a safer work environment, enhance worker morale, increase productivity, and reduce radiation dose by minimizing time in radiation areas.

What Causes Heat Stress?

Heat from the environment and metabolic heat from heavy work add to a worker's heat load. As core body temperature increases, blood flow to the skin increases and the body tries to lower core temperature by sweating. A person's heat exchange rate is represented by the following simplified equation(1):

$$S = M \pm C \pm K \pm R - E$$

where

S = heat exchange rate,
M = heat gained from metabolic activity,
C = heat loss or gain due to convection,
K = heat loss or gain due to conduction,
R = heat loss or gain through radiation,
E = heat loss due to evaporation of sweat.

If the heat exchange rate (S) is negative, the person loses heat energy and becomes cold. If it is positive, the person is not shedding heat energy as quickly as it is being produced or absorbed, and the person becomes overheated. In a typical D&D activity, heat loss through radiation (R) and conduction (K) is limited and workers lose heat energy primarily through evaporation (E) and convection (C). However, inside a worker's protective clothing, high temperature and humidity severely restrict the worker's loss of heat by evaporation and convection.

Innovative Technologies to Address Worker Heat Stress

The DD&D Focus Area has been promoting the development and deployment of several technologies to address worker heat stress. Current innovative approaches to improve workers' ability to shed excess body heat seek improvements in the breathability of PPE and the direct removal of heat energy through conductive heat exchange. Improved breathability of PPE reduces the temperature and humidity between the skin and the clothing to allow natural evaporative heat exchange processes to function more efficiently. Innovative heat conduction processes provide a heat sink where thermal energy is directly absorbed from the worker's skin. Besides PPE improvements, the DD&D Focus Area has also explored the use of a worker monitoring device to help mitigate the effects of heat stress.

In the development of improved PPE, consideration must be given to the fact that the use of PPE can itself create significant worker hazards. Besides heat stress, PPE can result in physical and psychological stress, and impaired vision, mobility, and communication. Trade-offs between weight, mobility, level of protection, and wearer comfort must be appropriately balanced. The DD&D Focus Area evaluates technology trade-offs in the context of actual field conditions. This is done through the Focus Area's Large-Scale Demonstration Program. In this program, innovative technologies are evaluated side-by-side with baseline technologies and meaningful, comparative data is taken and reviewed.

The following is a summary of each innovative technology within the DD&D Focus Area Program(2). A more complete description of each technology, its potential benefits, test results, and deployment successes will be described in the full paper.

<u>Heat Conduction Technologies</u>

Advanced Worker Protection Suit (AWPS). Oceaneering Space Systems (OSS) is developing and demonstrating the Advanced Worker Protection System (AWPS), a self-contained, breathing and cooling system. The AWPS uses a liquid-air backpack to provide air to workers for both breathing and cooling. Breathing air is provided to a pressure-demand respirator worn by the worker. Air is also used to cool water that is circulated in a liquid cooling garment worn against the worker's skin. The worker can wear either a two-piece splash protection suit (Level B protection) or a totally encapsulating suit (Level A protection).

Personal Ice Cooling System (PICS). This system, developed by Delta Temax, Inc., is a self-contained core body temperature control system that uses ordinary ice water as a coolant and circulates cool water through tubing incorporated into a durable, comfortable full-body garment. Ice is carried in bottles that are worn with anti-contamination suits in a sealed, insulated bag, with a circulating pump attached to a support harness system. An adjustable-rate, battery-powered pump circulates chilled water through the tubing in the suit, enabling the wearer to control the rate of cooling. The ice bottle, pump, and suit weigh only 12 pounds. The benefits of the PICS were demonstrated as part of the Fernald Plant 1 Large-Scale Demonstration Project (LSDP).

<u>Breathable Coveralls</u>

Protective Clothing Based on Permselective Membrane and Carbon Adsorption. Membrane Technology and Research, Inc. (MTR) is developing and demonstrating improved protective clothing that provides protection equivalent to current garments but is lighter weight to improve comfort and is breathable to allow water vapor to escape from the body, thereby reducing heat stress. Improved protective clothing will be made of an innovative fabric that combines an ultrathin, permselective outer membrane with a sorptive inner layer. The outer membrane is extremely permeable to water vapor escaping from the wearer, but highly impermeable to hazardous compounds. The sorptive inner layer captures any hazardous compounds that breach the outer membrane.

Sealed-Seam Sack Suits. As part of the C Reactor LSDP at DOE's Hanford Site, six different types of disposable protective coveralls were evaluated. The purpose of the demonstration was to determine whether disposable coveralls could be used to protect workers and minimize worker heat stress and whether costs could be competitive with baseline cotton coveralls. The comparison involved actual field use of the coveralls during the LSDP and also included laboratory analysis conducted at Los Alamos National Laboratory. The coveralls tested are all part of a new class of disposable coveralls that offer protection against radioactive and hazardous contaminants but also allow hot, moist air surrounding the wearer to escape. The suits were compared against standard cotton coveralls.

FHRAM-TEX Cool Suit and Nu-Fab Suit. As part of the CP-5 Reactor LSDP at Argonne National Laboratory, two different protective coveralls were field evaluated. Like the coveralls tested as part of the C Reactor LSDP, these disposable coveralls offer a strong and protective barrier to contaminants as well as keeping the wearer cooler. Unlike the cotton coveralls used as the baseline comparison at C Reactor, this demonstration used Tyvek coveralls as the baseline for comparison.

<u>Heat Stress Monitor</u>

Heat Stress Monitoring System. This technology, developed by Mini Mitter, is an on-line human monitoring system developed to monitor workers wearing protective clothing or working in environments where heat stress or other physiological safety issues are a concern. The unit displays temperature, heart rate, and activity data from 1 to 10 subjects working at distances up to 300 meters from the base monitoring station. The hot summer climate of the Eastern Washington was perfect for evaluating the Heat Stress Monitoring System, which was used to monitor workers wearing PPE. The Heat Stress Monitoring System remotely analyzes a worker's physiological state through a series of sensors: core temperature (ear canal), skin temperature, heart rate, and motion detector. Associated software polls the sensors several times per minute and alerts the work crew supervisor or safety personnel of parameters that could indicate that a person is under undue stress. The worker can then be removed from the work area to prevent an adverse reaction to the stress.

Summary

D&D projects typically involve conditions that can result in worker heat stress. The DD&D Focus Area believes that improvements to controlling worker heat stress are needed and attainable and is currently developing and demonstrating such technologies. Reduced worker heat stress will result in substantial benefits to DOE including improved safety and enhanced productivity.

References

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2. U.S. Department of Energy, *Decontamination and Decommissioning Focus Area Quarterly Report*, Federal Energy Technology Center, Morgantown, WV, January, April, July, and October 1997.